# Non-Newtonian Flows in Laminar Regime in Chevron Plate Heat Exchangers
# The Influence of Geometrical Configuration


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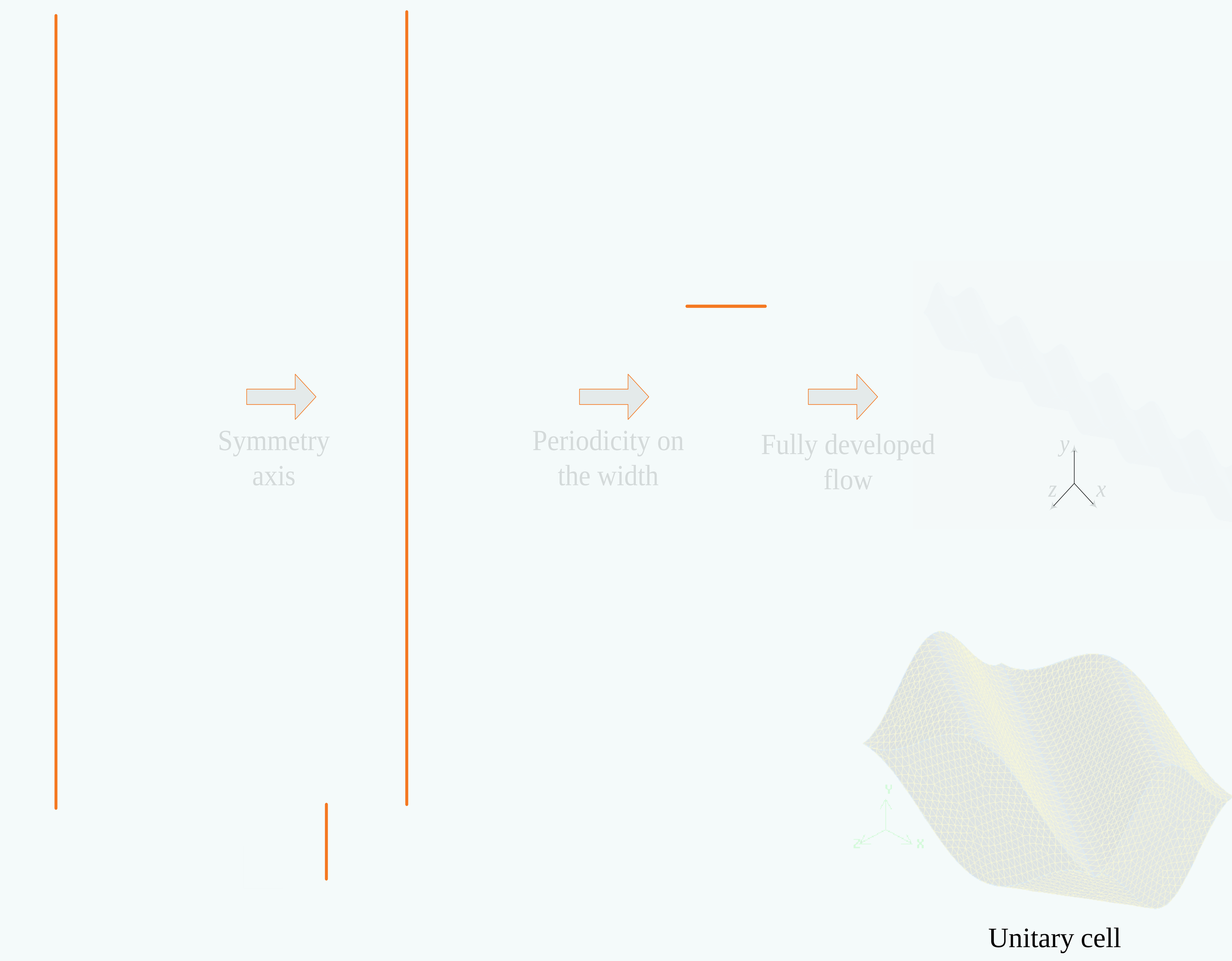
## 1. Introduction

Physical processing brings about irreversible textural and sensorial properties of nearly all the fluids on the food industry [1]. In liquid food processing, plate heat exchangers (PHEs) are commonly used in the heating or cooling stages due to their advantages, such as high efficiency, ease of maintenance and cleaning and flexibility on account of the modular design. Laminar or low Reynolds number, Re, flows are usually obtained when liquid foods are processed in PHEs, the thermal-hydraulic performance being strongly dependent on the geometrical properties of the chevron plates and shear thinning properties of the processed fluids.

## 2. Plate Heat Exchanger Channel

A uniform flow was considered inside each channel and, for this reason, a symmetry axis was established simplifying the geometrical domain to half of a channel . Analysing the results obtained in previous studies [2] with this geometry, it was possible to observe the periodicity of the flow along the width of the channel, which allowed the simplification of the geometrical domain to a thinner channel. The geometrical periodicity in the width of the channel could also be observed on its length. Periodic unitary cells could be found along the length of the channel. Local Fanning friction factors, *f*, and Nusselt numbers, Nu, were calculated in each of the consecutive unitary cells an asymptotic value being found on the fifth or sixth cell (hydraulic and thermally fully developed flows). Since the last cell was non-periodic, the simulations were performed in channels constituted by 7 consecutive unitary cells.

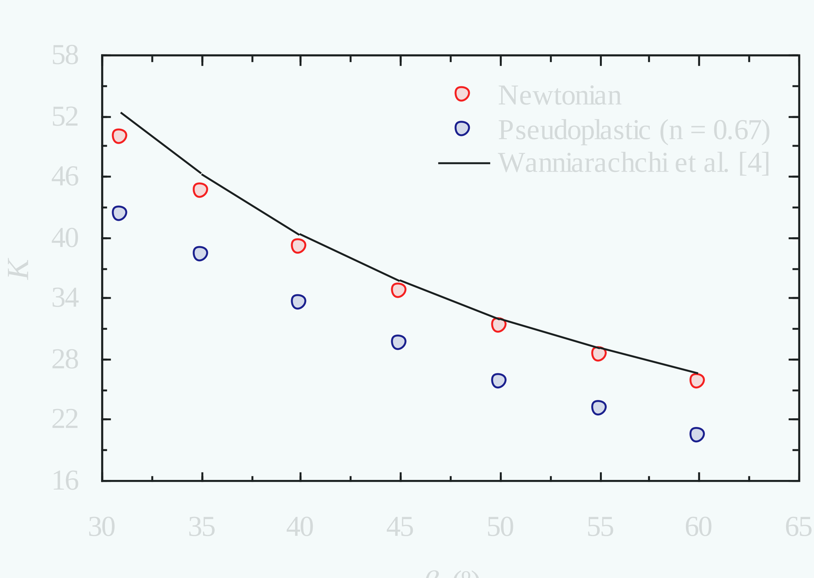
As in previous studies [2, 3], an unstructured mesh constituted by tetrahedral, hexahedral and pyramidal elements was used, the size of the elements being fixed after a grid independence test.

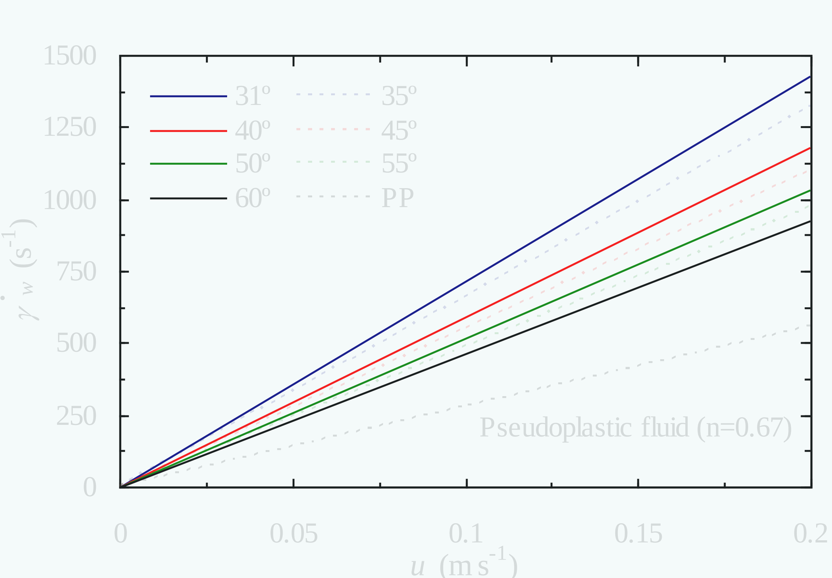


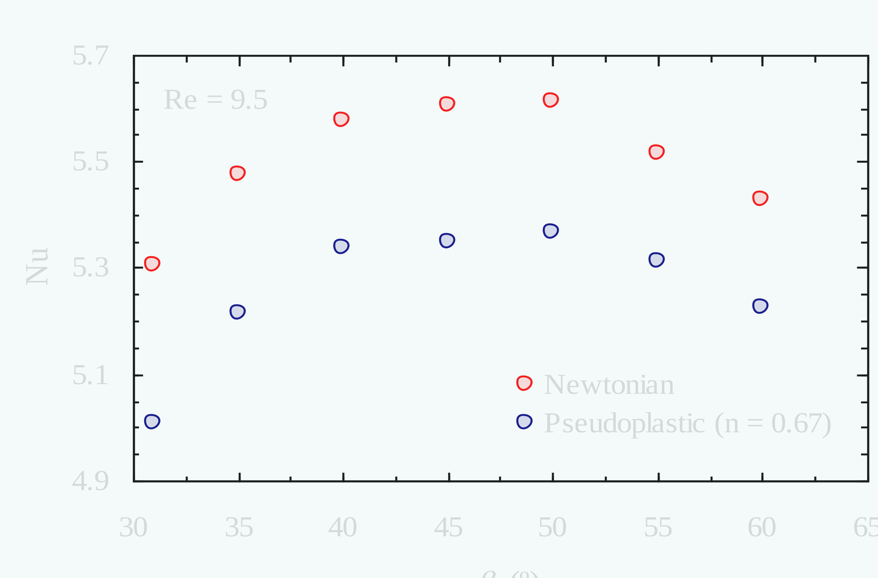

## 3. Results

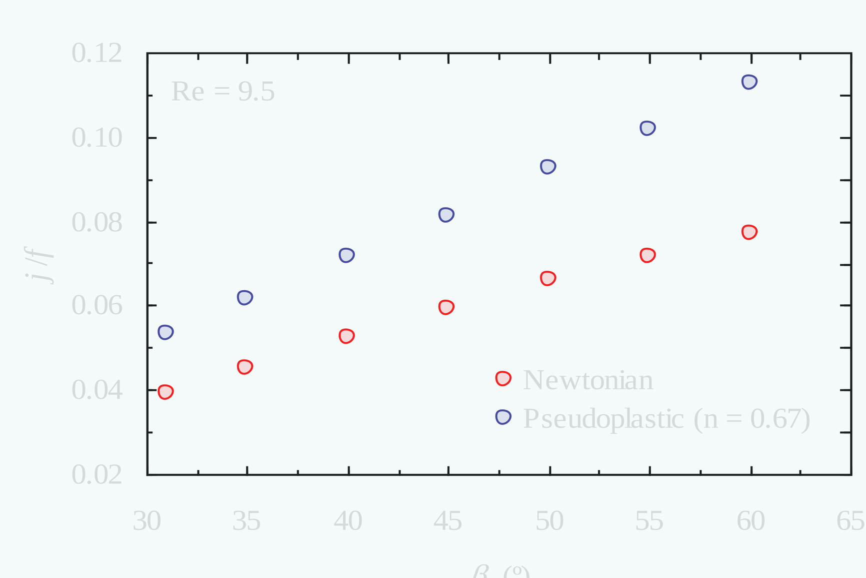
The influence of the corrugation angle, $\beta$, and shear thinning properties of the fluids on the thermal-hydraulic performance of PHEs was numerically studied using the finite element commercial package POLYFLOW. Non-isothermal laminar flows of a Newtonian and a power law fluid were numerically studied considering non-slip and constant temperature at the PHEs channels walls.

The pressure drop in each cell, the resultant values of *f* and Re numbers allowed the calculation of coefficient *K* present in the relation $f = K\,\mathrm{Re}^{-1}$. For Newtonian flows, coefficient *K* compares very well with literature data [4]. For the pseudoplastic fluid, due to the high shear rates (increase with the decrease of $\beta$) developed in PHEs channels and the shear thinning effect, *K* were much lower than those from Newtonian flows.



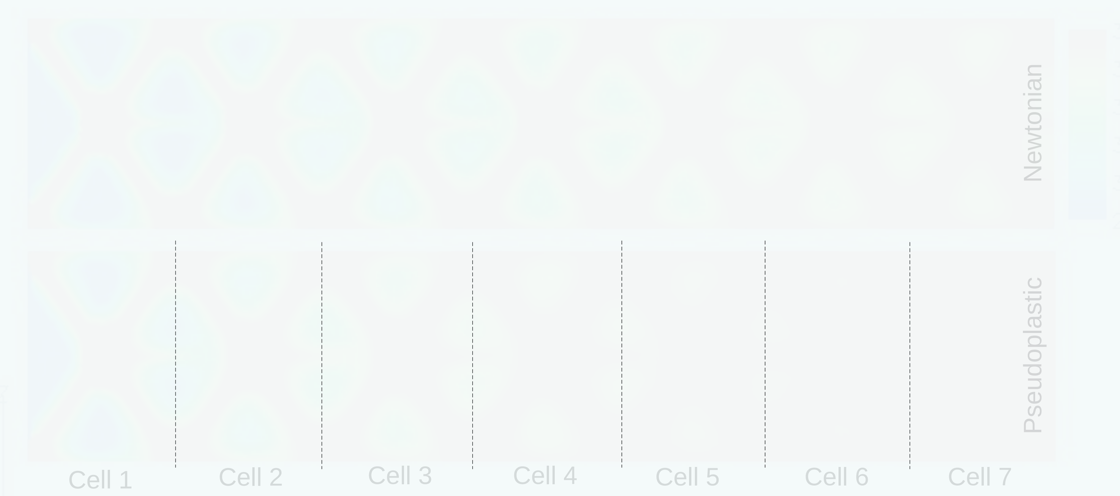




The temperature profiles allowed the calculation of the heat flux across each cell. Knowing the heat flux, temperature at the wall and average temperature in the cell, the convective heat transfer coefficients were estimated, which in turn were used for the calculation of the Nusselt numbers. For a same Re and $\beta$ a faster heating is obtained with the pseudoplastic fluid.

For a same Re number, Nu number reaches a maximum for $\beta \cong 50°$, this trend being interesting since is many times referred that Nu number increases with the decrease of $\beta$. As reported in works with other type of heat exchangers [5], the Nu numbers from the pseudoplastic fluid are lower than those from the Newtonian fluid. The higher thermal-hydraulic performance, *j/f*, obtained with the pseudoplastic fluid is therefore explained by the impact of the shear thinning effect on *f*.




## 4. Conclusions

When pseudoplastic fluids are processed in PHEs, high thermal-hydraulic performances are obtained due to the impact of the shear thinning effect in the Fanning friction factors. In the studied range, the thermal-hydraulic performance increase with the increase from the corrugation angle. In laminar regime, Nusselt number reaches a maximum in the interior of the common used chevron angles range. The estimation of wall shear rates can be useful to predict the viscosity breakdown of liquid foodstuffs during their processing in PHEs.

**References**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